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Explorer XII Observations of Magnetic Sudden
Impulses in the Earth's Magnetosphere

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The sudden, world-wide increases in the geomagnetic field intensity have been attributed to a compression of the magnetosphere, supposed due to an intensification of the solar wind. The analogous decreases, which are observed about half as often as the increases, are similarly explained by an expansion of the magnetosphere which results from a diminution in the solar wind intensity.[1,2] The compression and expansion phenomena are believed propagated through the magnetosphere to the surface of the earth by hydromagnetic waves.[3]

The successful operation of the flux-gate magnetometer on board Explorer XII (launched August 16, 1961) made possible the undertaking of a correlational study of geomagnetic field observations of ground-based magnetometers with the satellite observations at (geocentric) altitudes ranging from about three to thirteen earth radii (R_E). The Explorer XII magnetometer recorded the field approximately three times per second. Satellite data (points) discussed here have been obtained by averaging (arithmetically) over ten seconds. Errors in the averages are estimated less than ± 7 gammas. Presented here are two examples of Explorer XII magnetic records around the times of world-wide sudden impulses on the ground.

The first case, as shown (Figure 1) recorded by four widely-separated, middle and low-latitude magnetic observatories, is one of a positive sudden impulse (i.e., a world-wide increase in the field intensity). Shown is the behavior of the horizontal component of the field; for stations in the middle and low latitudes, the change in the declination is usually small.[2]

Plotted in Figure 2 are the ten-second averages of satellite measurements for the forty-minute interval around the onset of the impulse. Since interest here is in only those fields originating outside the earth itself, the contributions to satellite measurements due to sources within the earth are removed by subtracting the Jensen-Cain[4] field from those measurements. A trace of the horizontal component of the rapid-run magnetogram from the Honolulu station is superimposed on that plot.

The second case, shown in Figure 3, is a negative sudden impulse (world-wide decrease). The "corrected" field at the satellite level is illustrated in Figure 4, along with the rapid-run record from Honolulu.

Figures 2 and 4 indicate that world-wide sudden impulses observed on the ground appear in the satellite records with a small time discordance. Similar results have been found in several other instances not presented here. Included in these are a night-time observation (at the satellite local time $2^h\,00^m$, and altitude $\sim 3\ R_E$) and a high-altitude observation (at $4^h\,30^m$ local time, and an altitude $\sim 12\ R_E$). Since the sign of the impulses at the satellite level is the same as that observed on the ground, the electric currents responsible for these magnetic variations should then be outside the magnetosphere. This is consistent with the belief that the main part of world-wide sudden impulses is related to the magnetospheric boundary currents: positive impulses are caused by an intensification of the currents, thus giving rise to a compression of the magnetosphere; the negative impulses, on the other hand, result from a diminution of the currents, and thus an expansion of the magnetosphere.

The magnitude of the impulse at the satellite level is between one and three times that observed at the low latitude station, Honolulu.

In the case shown in Figure 2, where both the satellite and Honolulu are near the earth-sun line, the magnitude of the impulse at the satellite level is about 1.3 times as large as that observed on the ground. The strength of an image of the geomagnetic dipole field, with respect to a (boundary) plane located on the sunward side of the earth at the geocentric distance R, is given by $M(2R-r)^{-3}$ at a geocentric distance r on the earth-sun line, where M is the geomagnetic dipole moment. If the position of the boundary plane changes from R to $R-\Delta R$, the image field at r then increases by $6M\,\Delta R(2R-r)^{-4}$. According to the reported[5] observations of Explorer XII, the magnetospheric boundary lies generally around 10 R_E (taken here as R). Hence the theoretical value of the ratio of the increase in the field at the satellite altitude ($\sim 7\ R_E$) to that on that ground ($\equiv 1\ R_E$) based on the image dipole model is about 4.5. The apparent discrepancy between the calculated and the observed ratios can be attributed to the significant deviation of the shape of the boundary from a plane.

At the time of world-wide sudden impulses, the magnetic field changes in three to six minutes, both at the middle and low latitude regions of the earth and at the satellite altitudes. This is apparently the case for both positive and negative impulses. This fact seems to indicate that the sudden impulses propagate through the magnetosphere as infinitesimal waves, and not as "shock waves". The average propagation speed of the impulse between $\sim 7\ R_E$ and 1 R_E is estimated from Figure 2 as being $\sim 10^8$ cm./sec. A more reliable estimate is expected to result from the improved data processing which is now being undertaken.

No storm sudden commencements took place during the satellite observations within the magnetosphere.

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[2] Nishida, A., Ph.D. Thesis, University of British Columbia (1962)

[3] Dessler, A. J., and E. N. Parker, Hydromagnetic theory of geomagnetic storms, J. Geophys. Res., 64, 2239-2252, (1959)

[4] Jensen, D. C. and Cain, J. C., unpublished, presented at April 1962 meeting of AGU, Washington, D. C.

[5] Cahill, L. J., and P. G. Amazeen, The boundary of the geomagnetic field, J. Geophys. Res., 68, 1835-1843, (1963)

FIGURE CAPTIONS

Figure 1 An example of the positive world-wide sudden impulse shown by magnetograms from San Juan (abbreviated as SJ: Geomagnetic latitude: 29.9°N, Geomagnetic longitude: 3.2°). Trelew (TR: 31.7°S, 3.2°), Kakioka (KA: 26.0°N, 206.1°) and Toolang: (TO: 46.7°S, 220.8°).

Figure 2 Explorer XII magnetic record at the time of the sudden impulse shown in Figure 1, as corrected for the geomagnetic main field by the Jensen and Cain coefficients. Position of the satellite and the magnitude of the main field (abbreviated as J. C. Field) at the onset of the impulse are presented. Superposed with the same scale is the simultaneous magnetic record from Honolulu.

Figure 3 An example of the negative world-wide sudden impulse.

Figure 4 Explorer XII magnetic record and Honolulu magnetogram shown in the same way as Figure 2.

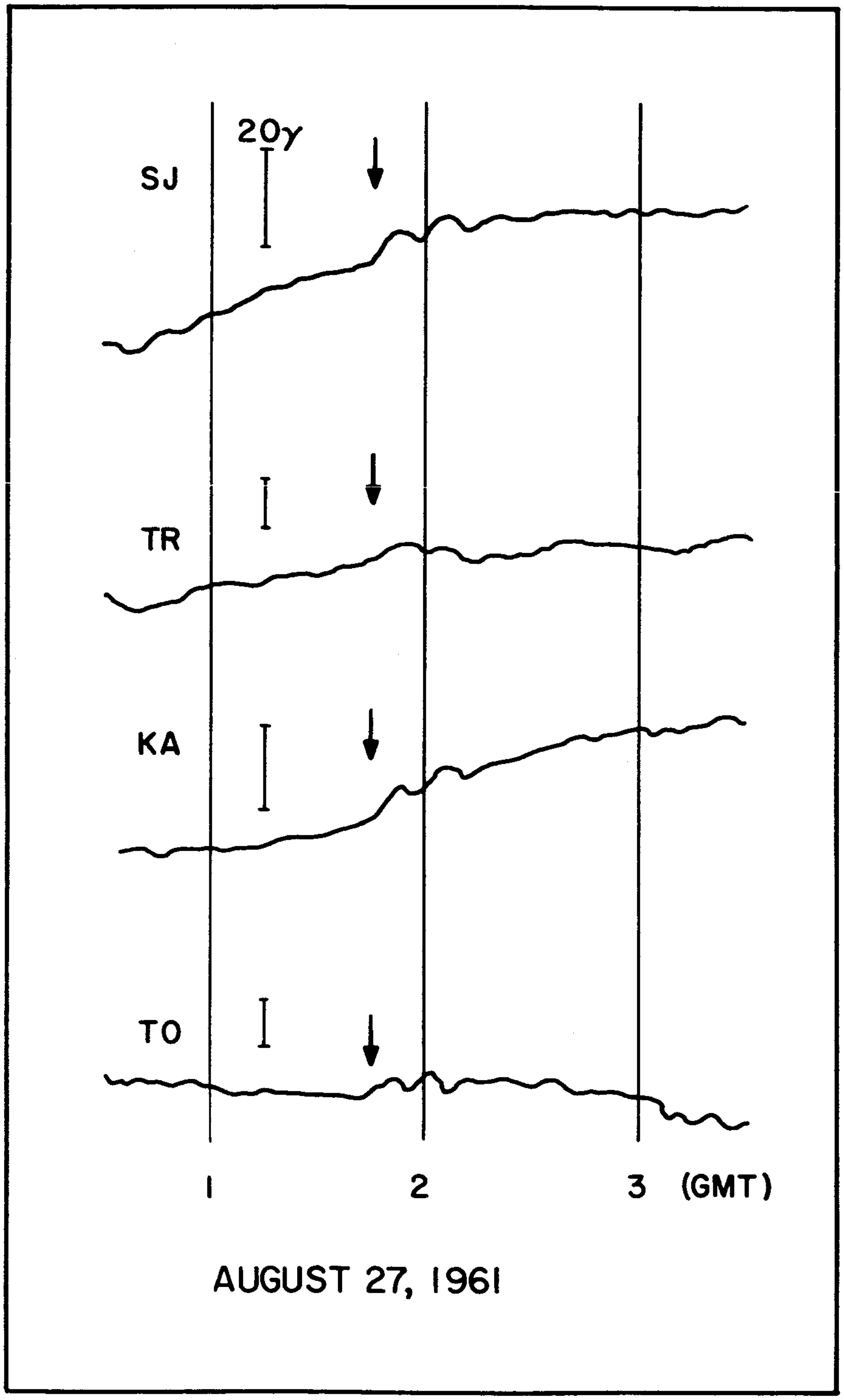

Figure 1

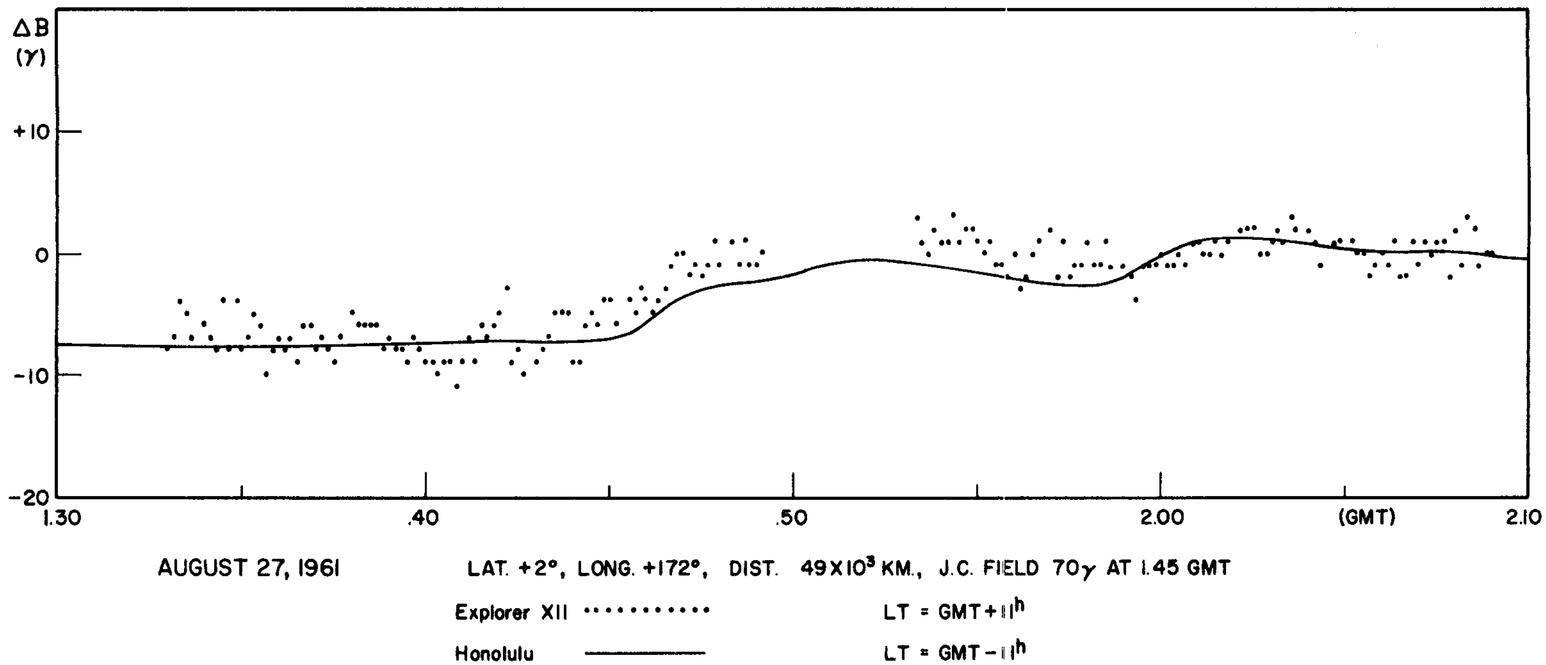
ΔB
(γ)
+10
0
-10
-20
1.30
.40
.50
2.00
(GMT)
2.10
AUGUST 27, 1961
LAT. +2°, LONG. +172°, DIST. 49X10³ KM., J.C. FIELD 70γ AT 1.45 GMT
Explorer XII
LT = GMT+11ʰ
Honolulu
LT = GMT−11ʰ

Figure 2

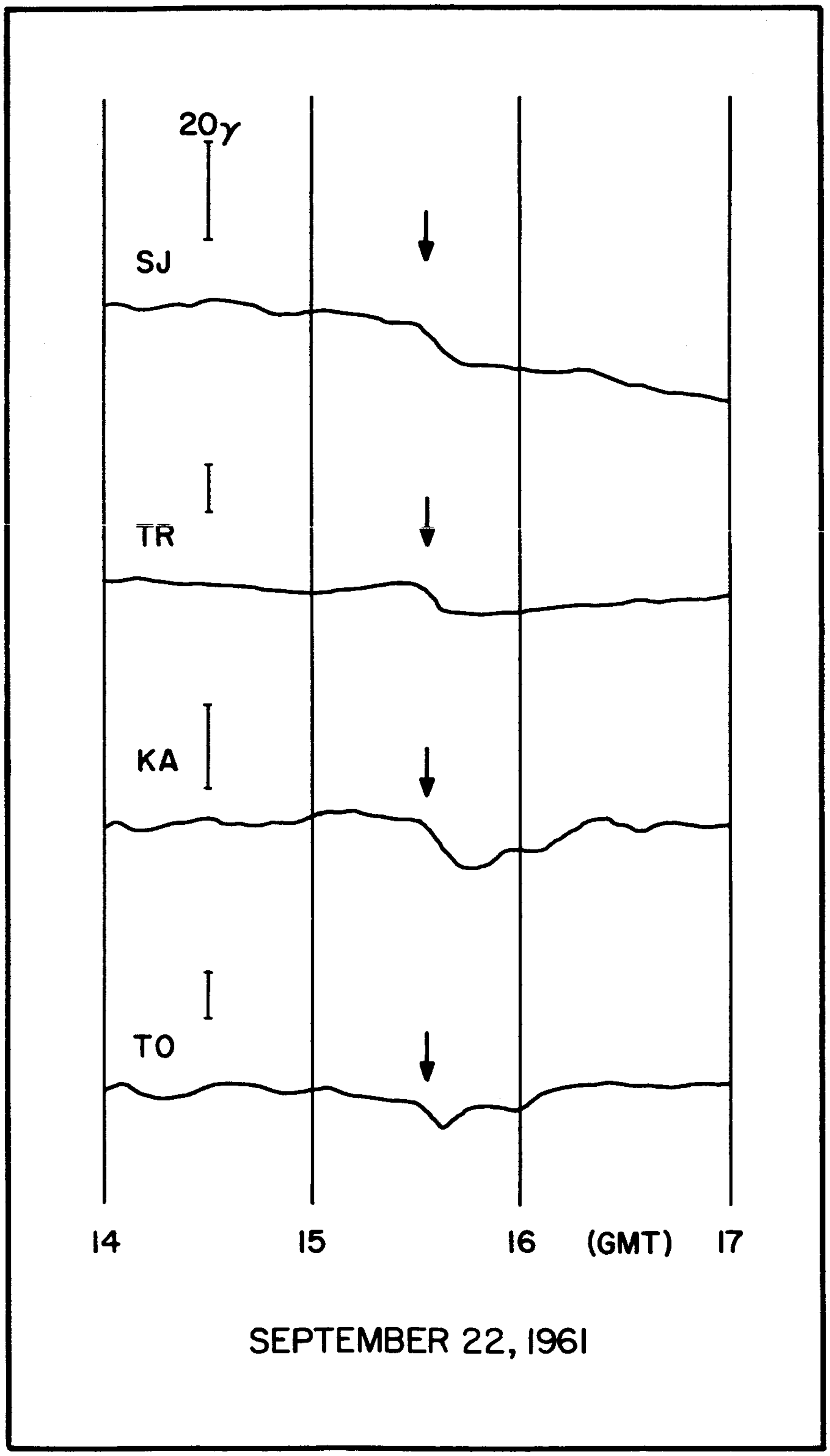

Figure 3

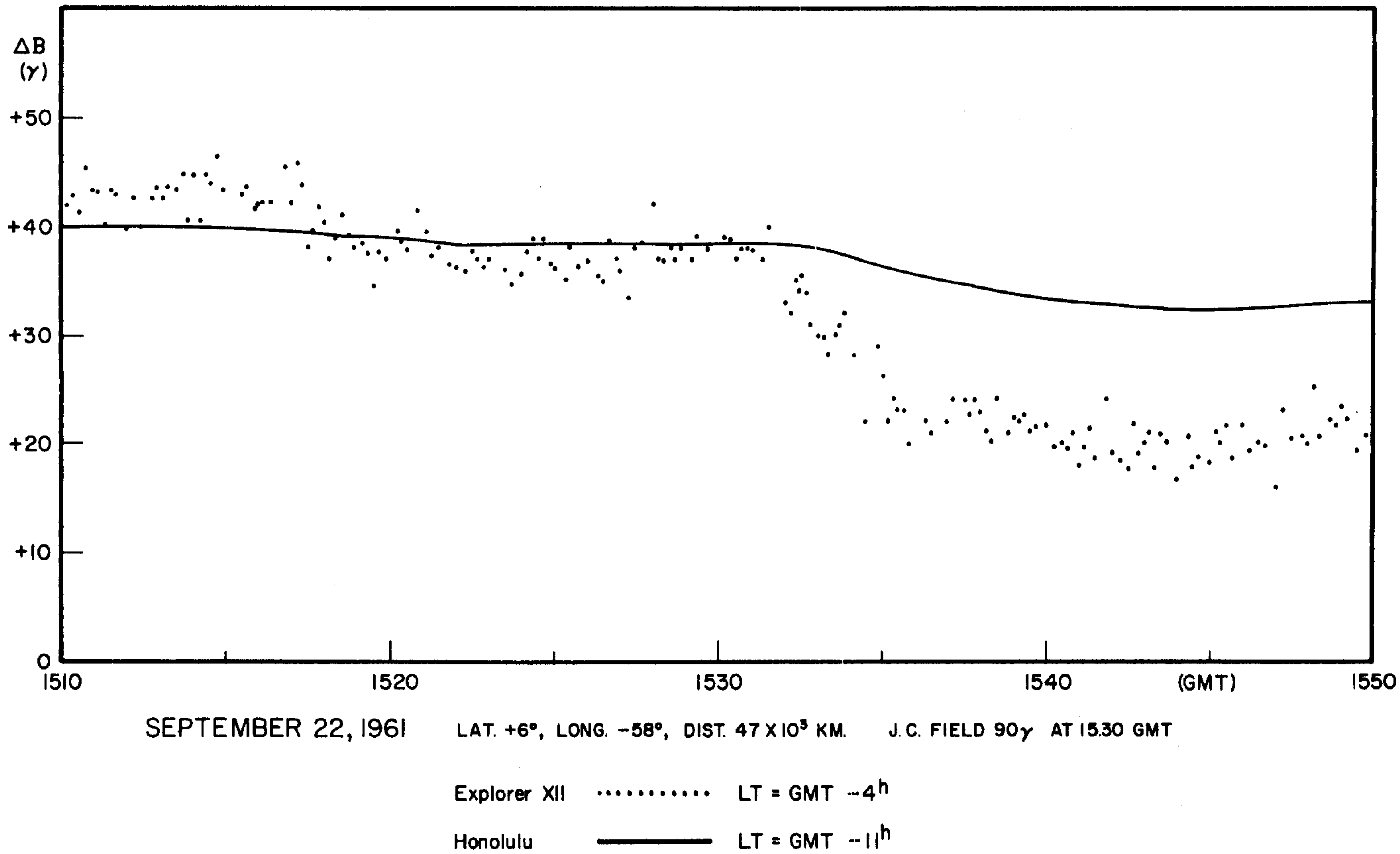
ΔB
(γ)
+50
+40
+30
+20
+10
0
1510
1520
1530
1540
(GMT)
1550
SEPTEMBER 22, 1961
LAT. +6°, LONG. -58°, DIST. 47 X 10³ KM.
J.C. FIELD 90γ AT 15.30 GMT
Explorer XII
LT = GMT -4h
Honolulu
LT = GMT -11h

Figure 4